

A Modulation & Ripple Level Meter

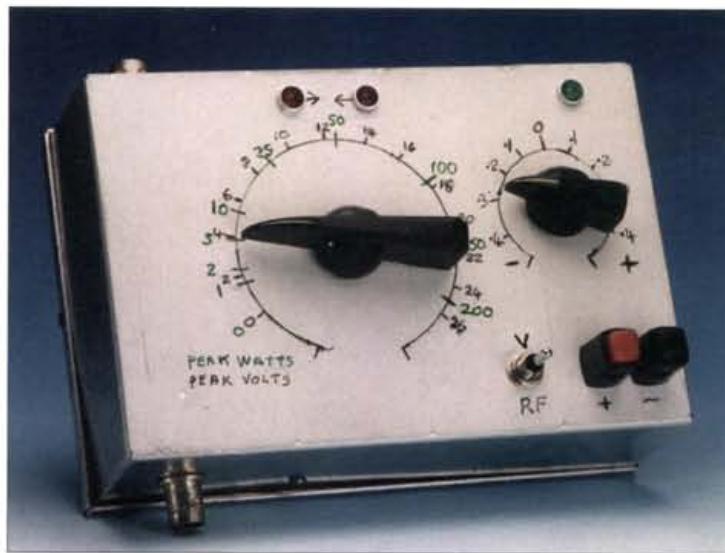
James Brett G0TFP shows you how to make a very useful meter that can be used to measure far more than the name suggests. Read on to see what it could be capable of in your workshop.

There are many measurements in Amateur Radio and general electronic design work that normally need an oscilloscope. For instance the radio amateur licence requires that, when using amplitude modulation (a.m. - A3E), the licensee makes measurements of percentage depth of modulation and of p.e.p. in s.s.b. (J3E) 'from time to time'.

When testing modulation depth, the transmitter waveform normally has to be viewed on an oscilloscope and the maximum and minimum amplitudes of the modulated carrier compared with the mean carrier level. For s.s.b. the transmitter output is again viewed and the two tone test used to indicate on the oscilloscope screen the peak power levels permitted.

This article describes a comparatively simple, easily built and calibrated accessory which will enable these and many other measurements to be made. The circuit monitors the r.f. current into a resistive load, rectifying it to produce the characteristic demodulated waveform as shown in Fig. 1.

The second part of the circuit enables measurement of the carrier level V_c shown as V_3 and the modulation peak $V_c + V_m$ (shown as V_2) in Fig. 1. A secondary function, without the r.f. section of the meter, the



measuring circuit allows measurements of ripple superimposed on d.c. supplies and many other useful measurements described later.

James Brett
G0TFP's
Modulation &
Ripple Level
Meter.

Circuit Description

The overall circuit of Fig. 2, shows the meter circuit and the sensing unit (connected between the transmitter output and a matched dummy load). Although the sensing head is designed for 50Ω impedances, other values will work. The coaxial inner line current is sensed by the transformer T1 (and its load, R11), is rectified by D1, capacitor C4 filters out the r.f.

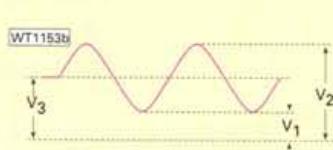
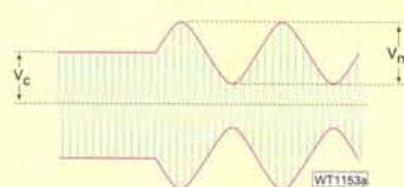
The recovered audio waveform across R12 is of a form, similar to that shown in Fig. 1. The audio signal (or a d.c. voltage with ripple) is applied, via S1 (shown in the modulation position) and the attenuating circuit of R2 and R3 to input pin 2 of the op-amp IC1, the main purpose of which is a gated level sensing circuit.

When the potentiometer R13 is at minimum, IC1 output will be high and D3 will be lit. As R13 is advanced a point will be reached where the level on pin 3 (IC1) will be just positive with respect to the negative peak of the applied waveform. The op-amp output will thus briefly 'pulse low'.

Advancing the potentiometer further will lengthen this negative pulse and D5 will start to glow, and D3 will dim. As the potentiometer is further advanced the point will be reached where pin 3 of the op-amp is just higher than the positive peak of the applied waveform, when D5 will be fully lit and D3 fully extinguished.

As it's difficult to determine accurately when the l.e.d.s are

Fig 1: The modulated 'envelope' and recovered audio signal from an amplitude modulated r.f. signal. See text for more detail.



Power (W)	Reading (V)
1	1.76
2	2.50
5	3.95
10	5.59
25	8.84
50	12.5
100	17.7
150	21.6
200	25.0

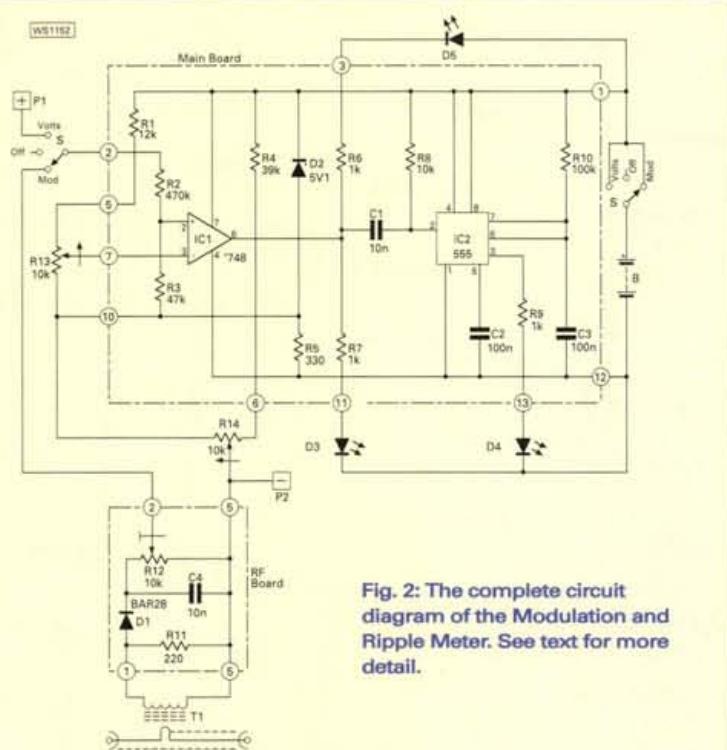


Fig. 2: The complete circuit diagram of the Modulation and Ripple Meter. See text for more detail.

extinguished or fully lit, the positive going edge of the op-amp output triggers IC2, a pulse lengthening circuit based around the 555 timer IC2. The duration of the pulse is set, by R10/C3, to approximately 9ms. Whenever the potentiometers are set in the 'ripple zone' and diodes D3 and 5 are flickering,

Two Main Units

The two main units are shown within dotted lines on Fig. 2, but layout is not critical and my prototype is shown in the annotated photographs. The layout can be modified to accommodate the shape of the box available. A separating screen between the r.f. and the rest of the circuit must be used to prevent possible interference to the metering circuits by the r.f. fields. My prototype is shown in the annotated photographs of Fig.s 3, 4 and 5.

The sensing transformer, T1, consists of 20 turns of insulated wire wound on a toroidal core, with tails left long enough to connect the r.f. strip board. The inner of the coaxial cable is passed through the centre of the toroid before soldering in place. The toroid and its winding are fixed in place with a generous application of a rubbery adhesive.

Variable resistors R13 and 14 are directly mounted in to the bottom of the box after first drilling the necessary holes and covering the outside with sticky white paper. The strip boards are supported by screws and extra nuts to space them from the box. The mounting holes on the strip boards should be slightly countersunk on the copper side and insulated washers used to prevent any of the strips short circuiting to the mounting nuts.

Test & Calibrate

It's now time to test and calibrate the unit, but first, carry out a careful wire check before connecting the battery. Connect a 'spare' fresh 9V battery to the input terminals (P1 and P2), observing correct polarity, and switch on to the 'Voltage' position of S1. Set R13 fully anticlockwise and R14 mid way, only i.e.d. D3 only should be illuminated.

Advance R13 slowly clockwise about a third of the way, at which point D3 will go out and D5 light. By varying R14 about the mid point, D4 should pulse on in keeping with the movements of R14. Now connect a transmitter and matching dummy load to the coaxial connectors.

Set the potentiometer R12 fully clockwise and switch on the transmitter at a low power level. Set the switch to the 'r.f.' position (as shown in Fig. 2) and check the unit's operation as described for the 'Volts' case. The unit is now functioning correctly.

To calibrate the potentiometer scales, an adjustable dc supply of 0-30V and a suitable voltmeter are required. Several (9V) dry batteries and a high resistance potentiometer (about $100\text{k}\Omega$) could be used instead.

With the switch set in the 'Volts' position set R14 to mid scale and mark the scale at this point as '0'. Now set the test supply to 2V and adjust R13 to the point where D3 and D5 just change over and mark this point 2. Carry on over the whole range of R13, marking the scale at appropriate points, say every 2V.

To calibrate R14, you use a similar method. Leave R13 somewhere mid scale, and the test supply set to the i.e.d. change over point. Now make small adjustments in voltage of around 0.1V intervals. By referring to Table 1 (see Fig. 1), the power calibrations can be marked around R13's scale.

Now you need to set R12 for correct reading. A 50Ω dummy load with a calibrated power meter is connected to one of the coaxial connectors and a transmitter with a 50Ω output is connected to the other.

Set R14 to '0', with the transmitter switched on, adjust its output to a convenient level as indicated on the power meter. Set R13 to the same power indication and adjust R12 to the point where D5 and D3 just change over. That is the calibration done! But what can you use it for? In answer to that look at the following:

Transmitter Power

The transmitter output is connected, via the unit, to a 50Ω dummy load. The transmitter should operate in f.m. or c.w. mode. With R14 set to the zero point, adjust R13 until the i.e.d.s 1 and 2 change over. Read the power directly of the

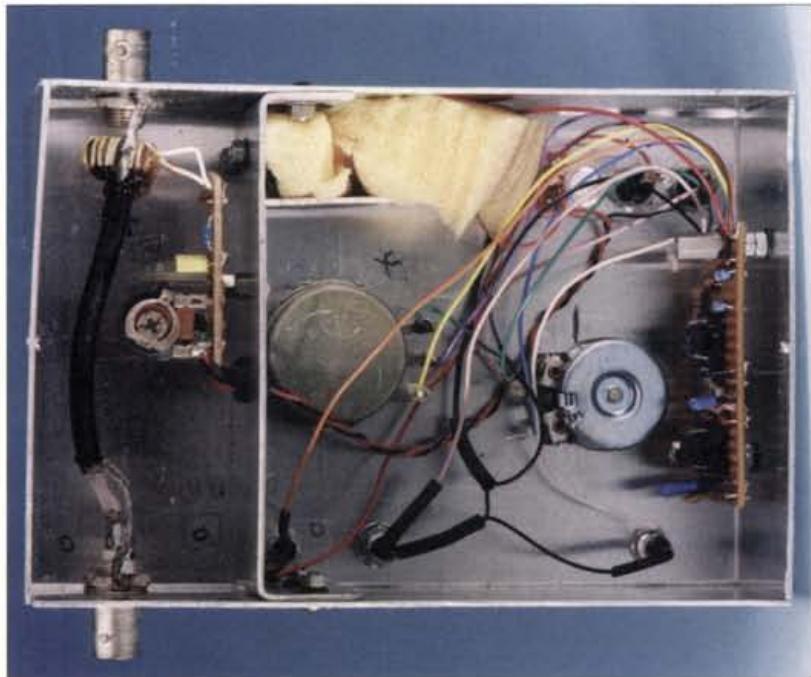


Fig. 3: Looking inside the Modulation and Ripple Meter, where variable resistor R13 and 14 are mounted on the 'front' of the box.

D4 will be brightly lit.

Potentiometer R13 has a dial calibrated in volts equivalent to the input voltage. The positive and negative peaks of the applied waveform are indicated as voltage measurements and will show in relative terms the actual current (and power) in the r.f. load. Operating as a fine control, R14 applies to a small shift to the applied input and is calibrated in fractions of a volt.

The circuit of D2/R5 enables the op-amp to be operated with 'balanced supply rails' from a single battery. The '748' type of i.c. was selected because, although it suffers some loss in performance, it will still give satisfactory gain at this low supply voltage.

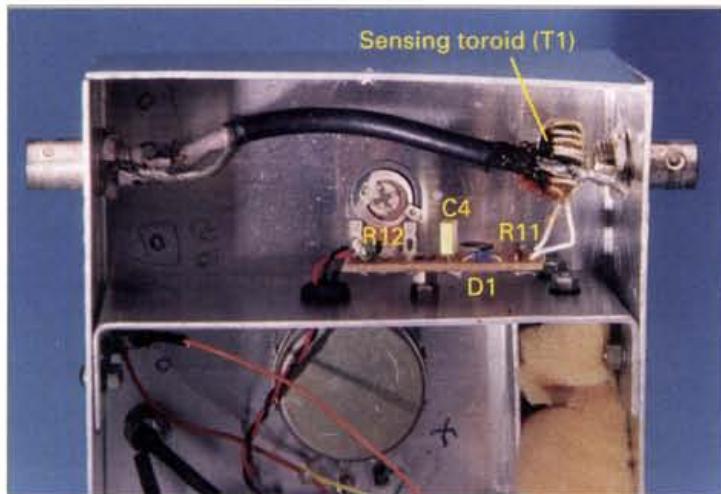


Fig. 4: A closer view of the sensing head.

scale of R14. If the r.f. system is mismatched or, if a different value of load is used, the power reading is no longer accurate, the scale, however can be used to show relative power levels when changes or adjustments are being made to the load or transmitter.

Modulation Depth

For assessing modulation depth you'll need a single audio tone input (an audio oscillator connected to the microphone input or an amplified audio oscillator and loud speaker in front of the microphone). Switch the transmitter to a.m. mode transmit, but without any audio input and measure the carrier level recording the voltage indicated by R13 and R14.

Now bring in the audio modulation and measure and record the peak voltage indicated by D5 being lit and D4 just extinguishing. You'll now have the voltages V3 and V2 as shown in Fig. 1.

The depth of modulation is:

$$\text{Modulation depth (\%)} = \frac{V_m - V_0}{V_m} \times 100$$

We have measured V_c as indicated by V3 and V_m which is given by V2 - V3. Thus the modulation depth is calculated by the formula:

$$\text{Modulation depth (\%)} = \frac{V_2 - V_3}{V_2} \times 100$$

This measurement is also true if the load is not accurately matched or the impedances are not 50Ω.

Peak Effective Power

Peak Effective Power (p.e.p.) is defined as the peak power supplied to the load during one radio frequency cycle at the crest of the modulation envelope. The Radio Amateur licence requires that any transmissions are limited to 400W maximum on some bands, less on other bands. It's recommended that the 'two-tone method' of measurement is employed, where two non-harmonically related equal amplitude audio tones are simultaneously used to modulate the transmitter as measurements are made.

The procedure is to fully modulate the transmitter with the two audio tones that produce a sinusoidal modulation envelope at the difference frequency of the two tones. This signal is fed to a power meter and the transmitter adjusted to show an average power level of 100W for the 400W p.e.p. case.

If monitored on an oscilloscope, the peak point of the signal is marked with a line on the screen. This line

represents the p.e.p. value of 400W and must not be exceeded during normal speech modulation.

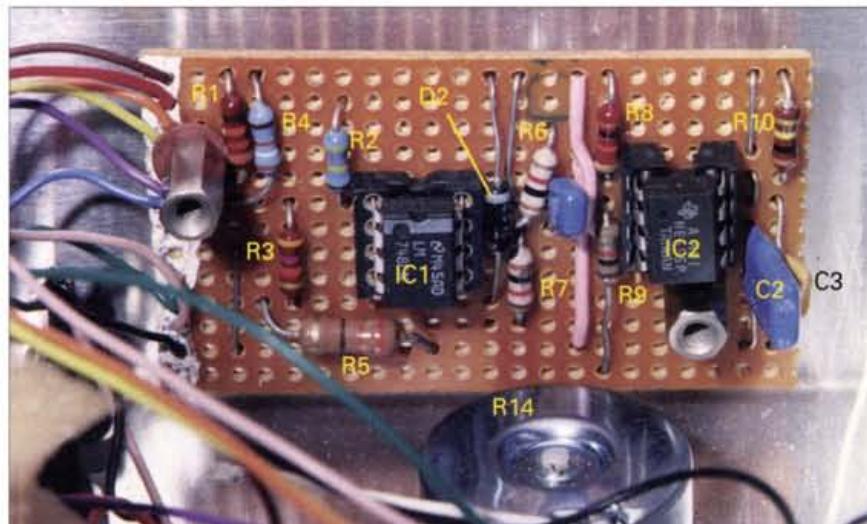
Using the Modulation Meter between the transmitter and the power meter, the signal is monitored as already described. With the two tone audio signal applied to the transmitter, the transmitter output is adjusted to indicate 100W on the power meter, then R13 is adjusted until, with D5 lit, D4 just extinguishes in effect this is the line marked on the oscilloscope screen.

Now with the antenna connected and normal speech modulation used, it is only necessary to set the transmitter modulation gain/level control to a position where the D4

does not pulse on even in the loudest speech points. And of course other p.e.p. level may be set by setting 25% of the required power level on the scale of R12

Ripple Measurements

With the switch S set to the 'Volts' position, P1 and P2 can be used to monitor the positive and negative peaks of the ripple in a power supply. The measurement is made by



turning up R13/R14 from zero until D4 just lights, for the lowest voltage (V1 in Fig. 1). Further advancing of R13 or R14 until D4 extinguishes indicates the maximum positive of the supply.

The facility is, of course, an important measurement when considering the design of a power supply on load. The input to the regulator can be checked to ensure that there's always sufficient voltage across the regulator for correct operation whatever the loading.

Other Uses

There are other uses of the meter, when it's used in the 'Volts' position. These include such things as amplifier output (before the capacitor coupling to the loud speaker) can be monitored. With no audio signal the mean voltage level can be determined by noting the readings where D5 and D3 just change over.

By now applying the audio the peak positive and negative excursions can be measured by observing the voltages when D4 just extinguishes. For a good amplifier these voltages should be equally disposed about the mean level previously measured.

Similarly, oscillator outputs and other circuit performances can be checked. There are, no doubt, other useful measurements which can be made, even to using it as a simple voltmeter when the workshop multimeter is not to hand.

Fig. 5: The prototype metering electronics were mounted on Veroboard for simplicity. Note! Due to the way the photograph has been taken there is some parallax distortion of component connections.